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XVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XLI. — ON THE EXCURSION OF THE DIAPHRAGM OF A TELEPHONE RECEIVER.

By Charles R. Cross and Henry M. Phillips.

Presented January 11, 1893.

The present investigation is a continuation of one upon the same subject by Messrs. Cross and Mansfield, the results of which have already been published in these Proceedings.*

In the study of the excursion of the telephone diaphragm described in the paper referred to, the current employed was an alternating current from a dynamo-electric machine, the magnitude of which current was considerably above that of the telephone currents employed in practice. In the present investigation we have employed the currents furnished by a powerful long-distance microphone transmitter to actuate the receiver, and have measured the amplitude of the vibration of the diaphragm of the receiver under such currents when the strength of the polarizing magnet was varied.

The apparatus employed was substantially indentical with that described in the paper referred to. A more sensitive electro-dynamometer with a unifilar suspension was used, and the support holding the disk of the receiving telephone was made somewhat more rigid, as it was found that it yielded slightly under the strong pull of the polarizing magnet when this was strongly magnetized, and in close proximity to the diaphragm. The microphone, actuated by a C_3 stopped organ-pipe of large scale, blown by a carefully regulated blast, was placed in the primary circuit of an induction coil, such as is ordinarily employed with the long-distance transmitter. In the secondary circuit was placed the receiving telephone, which was to be studied, and also the electro-dynamometer and an adjustible water resistance. In a few experiments the ordinary hand magneto-receiver was used, but in most cases we employed an experimental receiver like that used in the earlier studies referred to. The core was a bar of Norway iron, ¾ inch in diameter and 8 inches long, wound with 2,750 turns of No. 18 (B. & S.) insulated copper wire. The current which traversed these coils was furnished by a dynamo machine. It passed through an incandescent lamp and a variable resistance frame, with which last the magnet was placed in derived circuit. By varying this current any desired strength of field could be obtained. In all our experiments the core of the electro-magnet was far removed from saturation, so that we may assume the strength of its field to have been proportional to the current traversing its coils. The strength of this current was measured in the earlier experiments by a Thomson graded galvanometer, and in the later ones by a Weston milliamperemeter. The transmitter current was furnished by a single storage cell, and the organ-pipe which served as a source of sound was placed in a distant room. The arrangement of the stroboscopic fork was similar to that used in the previous work.

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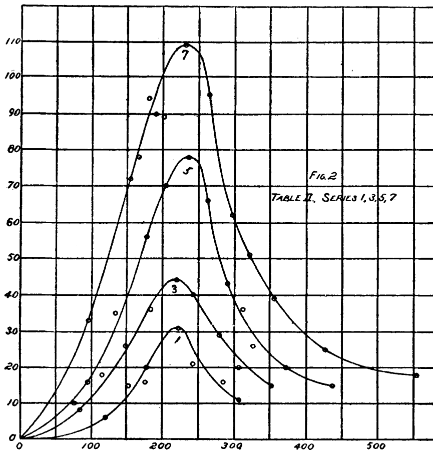
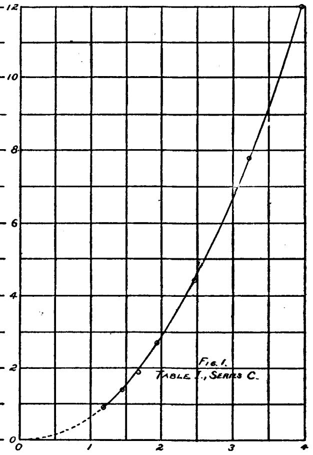
* *Ante*, page 93.





The first measurements were made with an ordinary magneto-telephone as a receiver. The line current was varied, and the corresponding excursion of the diaphragm determined, with the results given in Table I. Series C is graphically illustrated in Figure 1. The values given in the table are the mean of three or more closely concordant readings. In this and the following tables the current is given in milliamperes, the excursion in terms of one micrometer division as a unit. In the figures the abscissas represent currents, and the ordinates excursions.

TABLE I.

Series A.		Series B.		Series C.	
Line Current.	Excursion.	Line Current.	Excursion.	Line Current.	Excursion.
3.94	11.9	3.97	12.3	3.96	12.0
3.06	7.1	3.35	8.5	3.22	7.8
2.52	4.7	3.12	7.4	2.47	4.4
1.96	2.7	2.68	5.3	1.94	2.7
1.49	2.5	2.16	3.4	1.68	1.9
1.21	0.9	1.83	2.4	1.45	1.4
1.06	0.7	1.49	1.5	1.19	0.9
		1.30	1.1		

It appears from these results that with the magneto-receiver now used the change in the amplitude of the vibration is approximately proportional to the change in strength of the current for the stronger currents used in the measurements, but with the weaker currents the amplitude increases at a more rapid rate. These currents as a whole, however, are higher than those reached in practice.

In subsequent experiments we used as a receiver the electro-magnetic telephone previously mentioned. The end of its core was set at a distance of $\frac{1}{32}$ inch from the diaphragm. With the undulatory current in the line coil maintained at a constant value in each separate series of experiments, while the magnetizing current was varied, results were obtained as shown in Table II. Line currents with values successively varied in the different series were produced by the microphone transmitter. The values of the magnetizing currents in milliamperes are given in the first column, the corresponding excursions of the diaphragm in terms of one division of the micrometer in the second. Series I., III., V., and VII. are represented by the curves in Figure 2.

The results reached agree very well with those obtained by Cross and Mansfield, when currents from an alternating dynamo were used, except that in these last the maximum value of the excursion was reached with a magnetizing current of 320 milliamperes, while with those obtained in the present investigation the maximum value was reached when the magnetizing current was only 225 milliamperes. This difference arises from the fact that in the earlier experiments the end of the core of the magnet was set at a distance of $\frac{3}{64}$ inch from the diaphragm, while in the present ones it was at a distance of only $\frac{1}{32}$ inch, and so approached saturation sooner.

TABLE II.

Series I.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
120	6	176	16
178	20	243	21
153	15	285	16
223	31	307	11

Series II.

Line Current = 1.5 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
117	14	244	35
150	22	280	23
184	29	301	20
220	36	350	10

Series III.

Line Current = 1.9 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	8	244	40
115	18	280	29
149	26	306	20
184	36	352	15
220	44		

Series IV.

Line Current = 2.2 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
83	9	245	53
119	16	283	37
151	35	308	27
181	45	351	18
223	51	486	10

Series V.

Line Current = 2.6 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
75	10	263	66
95	16	291	43
135	35	312	36
178	56	327	26
204	70	372	20
237	78	438	15

SERIES VI.

Line Current = 2.8 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
74	11	287	51
119	31	301	42
160	44	355	25
181	56	327	33
219	75	481	13
249	68		

SERIES VII.

Line Current = 3.37 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	33	265	95
190	90	297	62
155	72	322	51
167	78	356	39
181	94	428	25
201	89	554	18
232	109		

Experiments were also made with the same apparatus in which the strength of the field magnet of the telephone was kept constant by maintaining a constant current in its coils, while the line current was varied. In the first series of these the diaphragm was separated from the end of the core by a distance of $\frac{1}{32}$ inch. The results are given in Table III., and Series VIII., IX., XI., XIII., and XIV. are graphically illustrated by the curves of Figure 3.

TABLE III.

SERIES VIII.

Magnetizing Currrent = 135 milliamperes.

Line Current.	Excursion.
3.15	33
2.76	27
2.05	14

SERIES IX.

Magnetizing Current = 160 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.46	73	2.29	32
2.98	56	1.72	23
2.74	46		

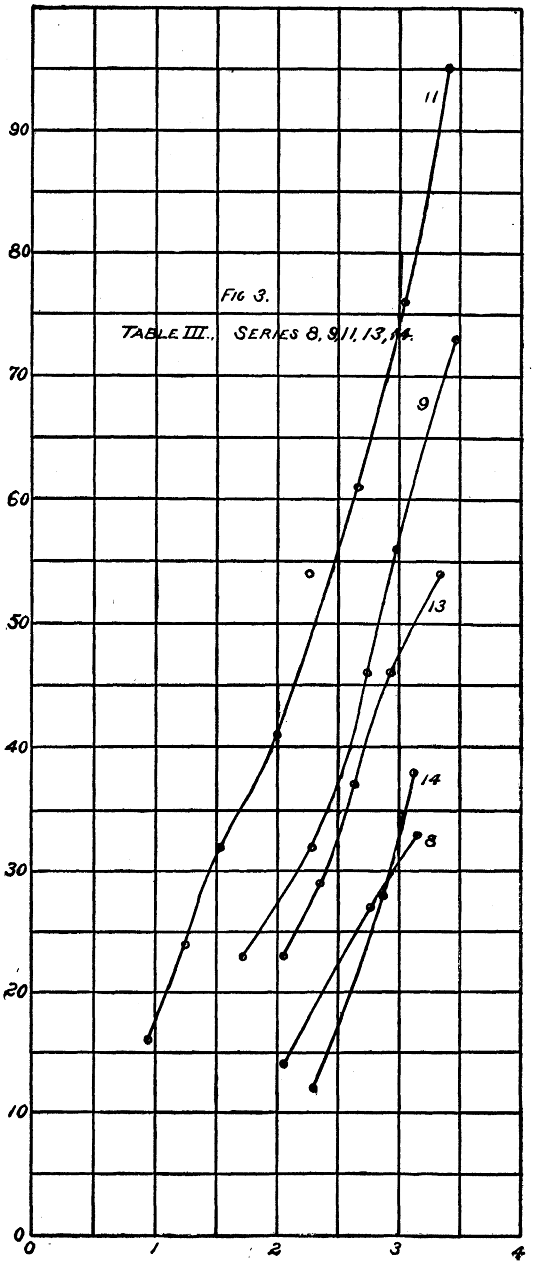


Fig 3.

Table III., Series 8, 9, 11, 13, 14.

Series X.

Magnetizing Current = 190 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.49	95	1.91	41
3.00	82	1.45	31
2.82	69	1.25	23
2.24	49	1.12	20

Series XI.

Magnetizing Current = 256 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
4.04	113	2.00	41
3.40	95	1.53	32
3.04	76	1.25	24
2.66	61	0.94	16
2.26	54		

Series XII.

Magnetizing Current = 259 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.77	98	2.29	47
3.23	83	1.87	34
2.78	71	1.53	23
2.51	56	1.19	16

Series XIII.

Magnetizing Current = 275 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.33	54	2.35	29
2.93	46	2.05	23
2.63	37		

Series XIV.

Magnetizing Current = 310 milliamperes.

Line Current.	Excursion.
3.12	38
2.87	28
2.30	12

These figures show that the change in the amplitude of the vibration of the diaphragm is approximately proportional to the change in strength of the line current within the limits of line current and magnetizing current used, and with the distance $\frac{1}{32}$ inch between the core and diaphragm. Some irregularities in the figures are due to a small variation in the strength of the magnetizing current, which was furnished by a dynamo machine whose speed fluctuated a little.

A series of observations was next made in which the magnetizing current was varied as with the previous Series I. to VII., and the line current kept constant, but with the diaphragm at a distance of $\frac{1}{64}$ inch from the pole of the field-magnet. The results are given in Table IV., and those of all the series except XVII. are shown graphically in Figure 4.

TABLE IV.

SERIES XV.

Line Current = 0.82 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
161	13	214	18
173	16	230	14
183	19	235	14
189	22	236	22

SERIES XVI.

Line Current = 1.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	11	182	18
117	16	191	18
135	20	207	25
150	23	209	29
169	17	217	31

SERIES XVII.

Line Current = 1.45 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
202	38	229	40
216	35	240	53

SERIES XVIII.

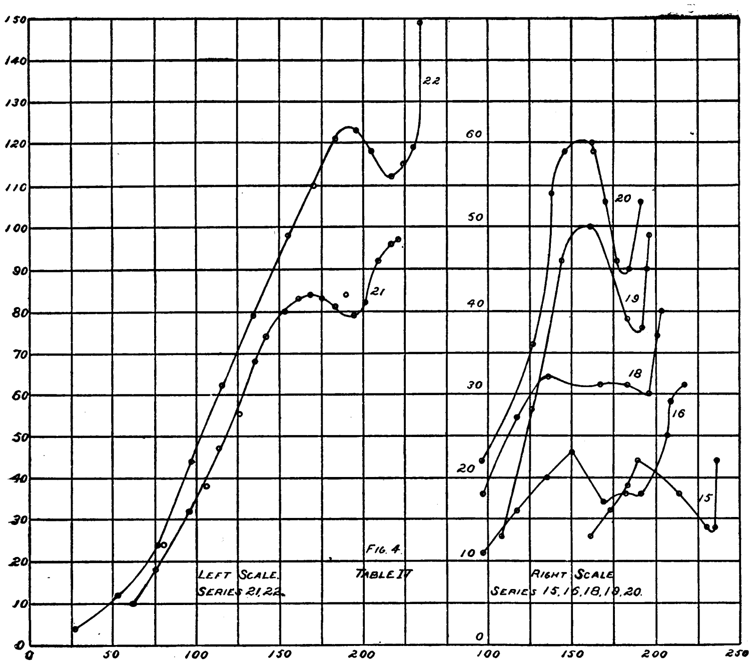
Line Current = 1.70 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
97	18	183	31
117	27	196	30
136	32	203	40
167	31	201	37

SERIES XIX.

Line Current = 2.05 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
108	13	183	39
126	28	192	38
144	46	195	45
161	50	196	49



Series XX.

Line Current = 2.18 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
96	22	163	59
127	36	170	53
138	54	177	46
146	59	184	45
162	60	191	53

Series XXI.

Line Current = 2.35 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
62	10	161	83
75	18	168	84
80	24	175	83
96	32	183	81
106	38	190	84
113	47	195	79
126	55	201	82
135	68	209	92
142	74	217	96
153	80	221	97

SERIES XXII.

Line Current = 3.55 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
27	4	183	121
53	12	196	123
76	24	205	118
97	44	217	112
115	62	224	115
134	79	230	119
155	98	234	149
170	110		

It will be noticed from the data given in the tables and the curves that with the core of the magnet at a distance of $\frac{1}{64}$ inch from the diaphragm, a first maximum of the excursion is reached with a magnetizing current not far removed from 160 milliamperes, while with a distance of $\frac{1}{32}$ inch the maximum excursion occurred when the magnetizing current had a value of about 225 milliamperes.

With the diaphragm thus close to the magnet, it was observed, as will be seen from the figures, that, after the amplitude of the vibration of the diaphragm had begun to decrease owing to the approach of the diaphragm toward saturation, there was a later increase of this amplitude, which rose even to an amount greater than for any previous value of the magnetizing current. This was brought about by the motion of the diaphragm towards the pole, the diaphragm assuming a new position of equilibrium under the increased pull of the magnet. The effect of increased proximity of the diaphragm to the core more than makes up for the opposing effect of a closer approach of the diaphragm toward saturation.

A separate study of the variation in the excursion after the second rapid rise began was made by using the strongest possible magnetizing current below that which pulled the diaphragm into contact with the core, viz. 204 milliamperes, and varying the line current, the excursions being measured as before. The results are given in Table V., and shown graphically in Figure 5.

TABLE V.

SERIES XXII *a*.

Magnetizing Current = 204 milliamperes.

Line Current.	Excursion.	Line Current.	Excursion.
3.15	137	2.10	66
2.86	122	1.74	48
2.63	98	1.34	30
2.37	83		

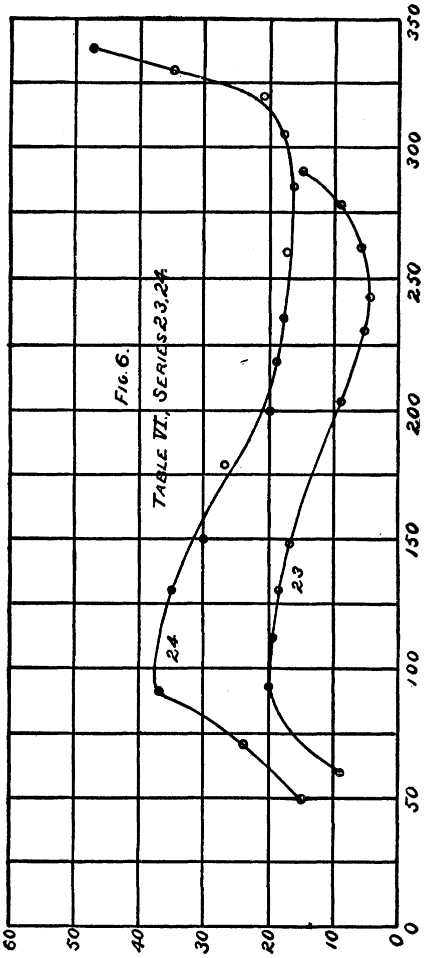


Fig. 6.

Table VI., Series 23, 24.

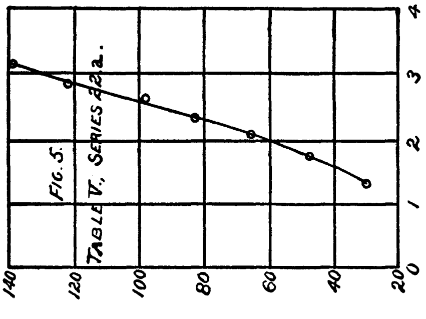


Fig. 5.

Table V., Series 22a.

Table VI. and Figure 6 show the result of a similar series of measurements with the diaphragm at a distance of $\frac{3}{256}$ inch from the core. Here the first maximum of the excursion is attained with a magnetizing current of about 100 milliamperes.

TABLE VI.

SERIES XXIII.

Line Current = 1.40 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
291	15	148	17
278	9	130	18.5
262	6	112	19.5
243	4 5	93	20
230	5.5	60	9
203	9		

SERIES XXIV.

Line Current = 1.65 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
338	47.5	200	20
330	35	179	27
320	21	150	30
305	18	130	35
285	16.5	91	37
260	17.5	71	24
235	18	50	15
218	19		

With the diaphragm at a distance of $\frac{1}{128}$ inch from the core, the values for the excursion given in Table VII. were obtained. These are shown graphically in Figure 7. Here the final rise of the curve has begun even with the lowest magnetizing force employed.

TABLE VII.

SERIES XXV.

Line Current = 1.26 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	26	39	10
51	18	28	7

SERIES XXVI.

Line Current = 2.25 milliamperes.

Magnetizing Current.	Excursion.	Magnetizing Current.	Excursion.
61	69	39	22
51	48	28	12

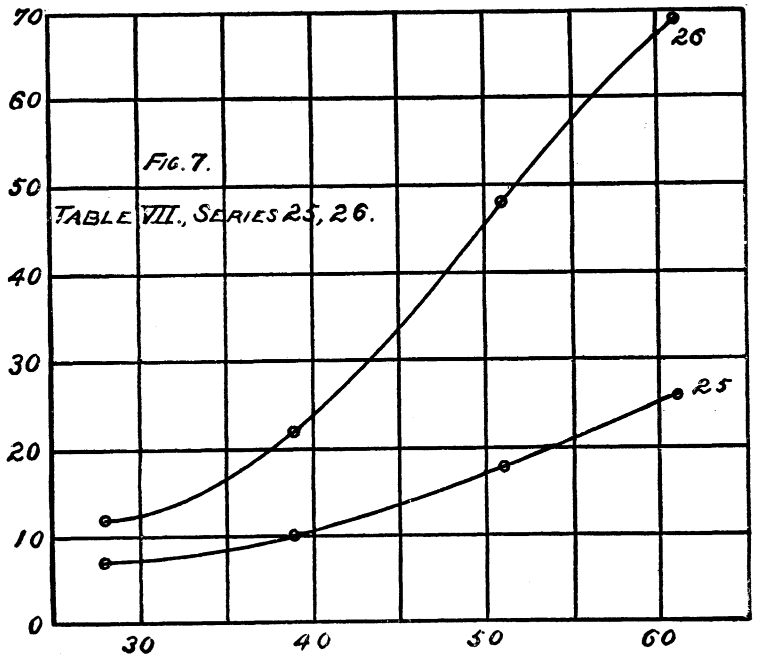


Table VIII. shows the manner in which the mean position of the diaphragm varies when the magnetizing current is increased. There is no current flowing through the line coil. The distance of the diaphragm from the core with no magnetizing current flowing was $\frac{1}{128}$ inch.

TABLE VIII.

Series XXVII.

Magnetizing Current.	Deflection.
0	0
14	12
28	48
39	145
50	286
61	546
72	1020

Rogers Laboratory of Physics,
June, 1892.